



Tentative Test Methods for Measuring Beam Divergence of Pulsed Lasers by the Apertured-Detector Technique¹

This standard is issued under the fixed designation F 524; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of the percentage of total beam energy contained in a given far-field divergence angle, without requiring the use of calibrated energy detectors. The methods make use of an apertured-detector technique.

1.2 These test methods apply to pulsed lasers in which the output polarization characteristics do not vary between successive pulses.

1.3 A single-detector method is used when the variation in energy from shot to shot of the laser under test is less than or equal to a value agreed upon by the parties to the test.

1.4 A double-detector method is used when the variation in energy from shot to shot of the laser under test exceeds a value agreed upon by the parties to the test.

1.5 The reported precision applies to lasers with cylindrically symmetric beam energy-density distributions. Deviation of the beam from cylindrical symmetry may decrease the precision of the test methods.

1.6 The appropriate test method may be applied for a given laser at a number of divergence angles and a relative beam-energy profile derived.

1.7 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For hazard statement, see Section 9.

2. Referenced Documents

2.1 ASTM Standards:

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods²

2.2 ANSI Standard:

Z 136.1 Safe Use of Lasers³

3. Terminology

3.1 Definitions:

¹ These test methods are under the jurisdiction of ASTM Committee F-1 on Electronics, and are the direct responsibility of Subcommittee F 01.02 on Lasers. Current edition approved June 24, 1977. Published August 1977.

² *Annual Book of ASTM Standards*, Vol 14.02.

³ Available from American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

3.1.1 *far-field energy distribution*—of a collimated source of optical radiation, such as a laser, the energy-density distribution present in the beam at a distance of several Fresnel lengths or greater from the source.

3.1.1.1 *Discussion*—A far-field energy distribution may be simulated through the use of a mirror or lens with a focal length that is on the order of 10 to 100 times the beam diameter at the focusing element. Such a focal length should be sufficient to reduce the effect of spherical aberration to negligible levels.

3.1.2 *fresnel length—in optics*, that distance from an aperture for which the value of the Fresnel number is exactly one for a given wavelength.

3.1.3 *fresnel number, N—in optics*, a dimensionless quality defined by the relation:

$$N = a^2 / d\lambda \quad (1)$$

where:

a = aperture diameter,

d = distance from the aperture, and

λ = wavelength under consideration, in consistent units of length.

3.1.4 *half-energy divergence angle*—of a collimated source of optical radiation, such as a laser that far-field angle containing one half of the beam energy; or for a pulsed source, one half of the energy in a pulse.

3.1.4.1 *Discussion*—The half-energy divergence angle is identical to the half-intensity divergence angle only for sources that have a gaussian distribution of beam intensity and are stable.

3.1.5 *near-field energy distribution*—of a collimated source of optical radiation, such as a laser, the energy density distribution present at the output port of the source or within a Fresnel length of the source.

4. Summary of Test Methods

4.1 Either the single-detector or the double-detector method is selected, based on the variation in energy from shot to shot of the laser to be tested.

4.2 Single-Detector Method:

4.2.1 A far field is simulated by focusing the laser beam by means of a long-focal-length spherical mirror or refracting lens. An aperture is positioned on the axis at the focal plane of the lens or mirror and the energy passing through the aperture is measured with a detector having approximately linear response with energy.

4.2.2 This measurement is carried out η times for each aperture that corresponds to a divergence angle of interest and is repeated η times with the aperture removed.

4.2.3 The percentage of total beam energy passing through the aperture is calculated for each shot in which an aperture was employed, using the appropriate detector measurement and the average energy measured with the aperture removed.

4.2.4 The averages and ranges of these percentages are calculated for each aperture.

4.3 *Double-Detector Method:*

4.3.1 A far field is simulated, an aperture is positioned, and energy through that aperture is measured as in the single-detector method. A pellicle or other beam splitter is inserted into the laser beam in front of the focusing element so that the transmitted portion of the beam passes through the focusing element and aperture and onto the detector as before. A second detector, also having approximately linear response with energy, is positioned to intercept that portion of the beam reflected from the pellicle to provide a reference energy measurement for each shot of the laser.

4.3.2 Measurements are made as in the single-detector method; the output of both detectors is measured each time the laser is fired.

4.3.3 The ratio of the first-detector measurement to the second-detector measurement is determined for each shot.

4.3.4 The percentage of total beam energy passing through the aperture is calculated for each shot in which an aperture was employed, using the appropriate calculated ratio and the average of the ratios obtained for those measurements made with the aperture removed.

4.3.5 The averages and ranges of these percentages are calculated for each aperture used.

4.4 The following items are unspecified in the methods and are to be agreed upon by the parties to the test:

4.4.1 The basis for determining shot-to-shot variation of the laser under test,

4.4.2 The maximum acceptable shot-to-shot variation for which the single-detector method is to be used,

4.4.3 The degree to which the detector response is linear,

4.4.4 The divergence angle or angles for which measurements are to be made, and

4.4.5 The number, of measurements, η , to be made at each aperture and without an aperture.

5. Significance and Use

5.1 These methods are suitable for use as routine acceptance tests.

5.2 These methods do not require the use of calibrated optical elements or calibrated detectors.

5.3 These methods are useful for evaluating the beam-divergence properties of commercial laser systems designed to have a given percentage of total beam energy contained within a given solid angle.

6. Interferences

6.1 Excessive beam-power densities or energy densities may damage the energy detector and result in erroneous measurements. Excessive beam-power densities or energy densities may also damage other elements, such as the pellicle

if used, with unpredictable results.

6.2 If the focal length of the focusing element is not long enough, spherical aberration at the focal plane may reduce the precision of the test methods.

6.3 Incorrect alignment of the aperture may reduce the precision of the test methods, as may failure to locate the aperture exactly at the focal plane of the focusing element.

7. Apparatus

7.1 *Single-Detector Method:*

7.1.1 *Energy Detector*—A means for measuring beam energy at the laser wavelength involved. The detector output or reading shall be a linear function of beam energy incident on the sensing element of the detector over an energy range corresponding to the range of energies to which the detector is exposed, as agreed upon in 4.4.3. The detector shall be capable of receiving the beam in question without experiencing damage or loss of performance.

NOTE 1—If the beam energy of a laser under test is reduced sufficiently by suitable means, a given detector may be used to measure the energy of a laser that would otherwise exceed the energy capability of the detector (see 7.1.6).

7.1.2 *Focusing Element*—A spherical mirror or single-element (uncemented) lens with a known focal length of at least ten times the beam diameter at the element and of sufficient diameter to collect all the coherent radiation emitted by the laser.

NOTE 2—The focal length as specified is intended to be long enough to render negligible the effects of spherical aberration. For extra assurance, a focal length of 2000 mm has been used for beam diameters of up to 100 mm.

7.1.3 *Prism*—A right-angle prism to be used in conjunction with a spherical mirror, as shown in Fig. 1 (not required if a lens is used as the focusing element).

7.1.4 *Aperture Plate*—A disk or plate with one or more apertures providing the divergence angles agreed upon by the parties to the test.

NOTE 3—An example of an aperture plate is shown in Fig. 2. The disk shown is ceramic with apertures of diameters from 0.2 to 20 mm.

7.1.5 *X-Y Positioning Support*—A means for (1) supporting the aperture plate in a plane perpendicular to the plane of the table or bench rails, and (2) positioning the plate in two orthogonal directions.

7.1.6 *Means to Reduce Beam Energy*—if required, bare glass mirrors or other means customarily used to reduce beam energies.

7.1.7 *Scale*—Machinist's scale or other means suitable for measuring distances between optical components on the table or bench.

7.1.8 *Supports*, suitable for use with the table or bench (as required) for the various optical components and for the laser under test.

7.1.9 *Table or Bench*—Optical table or bench on which the laser under test and the optical components may be set up. The table or bench shall satisfy the requirements customarily specified for similar purposes.

7.2 *Double-Detector Method:*